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Proceedings of the Centre of Science Advice, Pacific Region. Assessment of Pacific sardine in British Columbia waters, with an emphasis on seasonal abundance and migration estimates.

Compte rendu du Centre des avis scientifiques de la région du Pacifique. Évaluation des sardines du Pacifique dans les eaux de la Colombie-Britannique, principalement axée sur des estimations saisonnières de leur abondance et de leur migration.

January 18, 2011
Nanaimo, BC

Janvier 18, 2011
Nanaimo, C-B

Sean MacConnachie, Chairperson

Sean MacConnachie, président de réunion

Fisheries and Oceans Canada / Pêches et Océans Canada
Pacific Biological Station / Station biologique du Pacifique
3190 Hammond Bay Road
Nanaimo, BC / C.-B. V9T 6N7

January 2012 | **Janvier 2012**

Canada

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

Avant-propos

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d'analyses ou d'interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenues dans le présent rapport puissent être inexactes ou propres à induire en erreur, elles sont quand même reproduites aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considérée en tant que reflet des conclusions de la réunion, à moins d'indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l'information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

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TABLE OF CONTENTS

SUMMARY v
SOMMAIRE v
INTRODUCTION 1
REVIEWS 1
GENERAL DISCUSSION 2
SUBCOMMITTEE CONCLUSIONS 4
SUBCOMMITTEE RECOMMENDATIONS 4
ACKNOWLEDGEMENTS 4
APPENDIX A: AGENDA 5
APPENDIX B: ATTENDEES 6
APPENDIX C: TERMS OF REFERENCE 8
APPENDIX D: DETAILED REVIEWS 11

SUMMARY

A Regional Advisory Process (RAP) was held in January 2011 in Nanaimo BC to review the feasibility of developing a seasonal estimate of sardine biomass in the Canadian zone from the summer research trawl survey data independent of the U.S. stock assessment, and to provide advice on seasonal abundance and/or migration to apply to harvest control rules and set quotas for the 2011/2012 fishing season.

Participation in this meeting included staff from Fisheries and Oceans Canada (DFO) Science, Fisheries and Aquaculture Management, and external participants from the Provincial Government, non-governmental organizations, academia, industry and professional consultants.

The results of this meeting are to be used to support management decisions related to the commercial sardine fishery.

SOMMAIRE

Un processus consultatif régional (PCR) s'est amorcé, en janvier 2011, à Nanaimo (C.-B.), afin d'examiner la faisabilité de produire une estimation saisonnière de la biomasse des sardines dans la zone canadienne, à partir des relevés au chalut effectués dans le cours de l'été, indépendamment de l'évaluation des stocks des États-Unis, d'une part, et de fournir, d'autre part, des avis sur leur abondance et leur migration saisonnières en vue d'appliquer des règles de contrôle des pêches et de fixer des contingents pour la saison de pêche 2011-2012.

Au nombre des participants à la réunion, il convient de mentionner notamment les employés des secteurs des Sciences et de la Gestion de pêches et de l'aquaculture de Pêches et Océans Canada (MPO), ainsi que les gens de l'extérieur provenant du gouvernement provincial, des organismes non gouvernementaux, du milieu universitaire et de l'industrie et les consultants professionnels.

Les résultats de cette réunion serviront à appuyer les décisions de gestion concernant la pêche commerciale de la sardine.

INTRODUCTION

A Centre for Science Advice – Pacific (CSAP) review was held on January 18, 2011 at the Pacific Biological Station in Nanaimo, British Columbia. External participants from industry and First Nations were in attendance at the meeting. American colleagues also participated via Webinar. The Subcommittee Chair (S. MacConnachie) opened the meeting by welcoming participants, reviewing the agenda and reviewing to the terms of reference.

The CSAP participants reviewed the following working paper:

- "Evaluation of Pacific sardine (*Sardinops sagax*) stock assessment and harvest guidelines in British Columbia" by Linnea Flostrand, Jake Schweigert, Jackie Detering, Sean MacConnachie and Jennifer Boldt.

REVIEWS

Working Paper reviewed: Evaluation of Pacific sardine (*Sardinops sagax*) stock assessment and harvest guidelines in British Columbia" by L. Flostrand, J. Schweigert, J. Detering, and S. MacConnachie and J. Boldt.

**Paper was accepted subject to revisions*.*

The main objective of the working paper was to evaluate alternative harvest guideline rules, namely the development of a seasonal sardine biomass estimate independent of the U.S. stock assessment. Formal reviews were provided by Robert Emmett (NOAA, NMFS) and Marc Trudel (DFO). Both reviewers agreed that the working paper was well written. Both reviewers identified the calculation error of U.S. harvest rate in Table 9. Emmett and Trudel also felt it would be appropriate to include a reference on bootstrapping methods. Authors agreed to address each of these recommendations.

Dr. Emmett

The chairperson presented the review on behalf of Dr. Emmett. The reviewer provided two references that report on size and age of sardine off California from research surveys that would be more appropriate than using the commercial landing data currently presented in the working paper. The California fishery information is spatially limited to nearshore areas and does not represent trends in size of fish in the offshore zone. Authors agreed to incorporate these data into the working paper. Emmett also noted that since migration rate of sardines into Canadian waters is strongly affected by temperature, there should be discussion regarding oceanographic conditions. He highlighted that the U.S. incorporates temperature into their Harvest Control Rule, and that perhaps the Canadian guideline should do so. Authors appreciated his input and agreed that wording around ocean conditions be included in the paper.

Dr. Trudel

Dr. Trudel recommended that sardine biomass in inshore waters be assessed independently from the survey instead of assuming that the density within inshore areas is the same as the WCVI survey density. Authors explained that trying to estimate density for some areas outside the core area (especially inlets) is challenging i.e. unable to trawl with the R/V W.E. Ricker in many areas as well as conservation concerns for sensitive salmon stocks in a number of the inlets. Authors noted that as an alternative to trawl surveys in inshore areas, aerial surveys have been undertaken in 2009 and 2010. Photographs taken in 2010 are currently being analysed. Trudel went on to highlight that Canada needs to improve coordination with U.S. if migration rate changes from year to year. Coastwide exploitation rate may exceed 15%, if the migration rates to Canada increase and the U.S. maintains the assumption of 87% distribution in their

waters. The authors agreed with this point, but felt that additional discussion with U.S. scientists would be required to better understand how this is incorporated into their harvest advice. Trudel warned against over/under harvesting due to reliance on the previous year's biomass estimates. His recommendation for an in-season biomass estimate generated discussion among attendees. The authors acknowledged that future work could examine the feasibility of using the coastwide biomass estimate of semester 2 (S2: January to June) instead of semester 1 (S1: July to September) which is currently part of the Canadian harvest control rule. In his review, Trudel indicated that adopting a minimum threshold may be an option worth including in the Canadian HCR. It was not immediately clear how this could be done since the likelihood is that as the population declines fewer fish would migrate into Canadian waters making a Cutoff level unnecessary.

The authors also agreed to make corrections to minor editorial points identified by each reviewer.

GENERAL DISCUSSION

Survey design

Concern was expressed that introduction of a new trawl design methodology (randomized grid) may compromise the comparability of the 2010 data to the rest of the time series (transect method). The authors explained that both methods would produce similar density estimates, however in an effort to improve statistical rigour, the randomized grid method will be employed in future surveys. The authors recognized that post-survey analyses could help improve the comparability of the different survey methods. One participant expressed concern that the current bootstrapping method may be underestimating the variance of density estimates and suggested improvements would treat transect lines as unique sampling units and randomized grid stations as points.

The differential treatment of areas of high and low densities in post-sampling stratification was another suggestion. Concern was raised about the calculation of a mean with a dataset having a large proportion of zero catches. The authors and the participants reassured the group that using the bootstrapping method is an acceptable and appropriate way to handle the data. There was discussion around the assumption that sardine depth distribution may be less or more than the assumed 30m of surface waters. Previous studies of WCVI surveys demonstrate that this assumption is reasonable. Some discussion also explored the challenges of adopting an in-season biomass estimate: uncertain platform access, limited resources, time constraints and extensive spatial distribution were noted.

It is assumed that the timing of the annual survey captures the peak migration of sardines into Canadian waters. Harvesters thought it was important to capture the trend in the harvest season. Namely the increase in catch over time may indicate that peak migration into B.C. waters happens later in the season, after the trawl survey has been completed. Furthermore, concern was raised that in 2010, anomalous oceanographic conditions might have resulted in unusually low density estimates. Authors agreed that the paper would benefit from additional discussion on the unusual temperatures during the beginning of the 2010 sardine survey. Furthermore, the idea of incorporating environmental factors in the prediction of sardine abundance in B.C should be explored in future work.

Further development of alternative harvest control rule options

The view that alternative harvest control rules could be further developed was expressed. One suggestion was to use a three year running average instead of simply the previous year's biomass estimate. This would help buffer the highs and lows observed in the annual sardine biomass estimates. However it was noted that the previous three years of data have been shown not to be predictive of the following year.

Inshore areas

There was some discussion around the assumption that density is similar between WCVI and inshore areas. Some found it to be an inappropriate assumption, lacking proper justification. It was suggested that perhaps evaluating catch per unit effort (CPUE) of commercial catch in the inshore areas might help expand knowledge. Several participants cautioned that CPUE of pelagic fish are poor indicators of abundance due to the fleet's high success in capturing schools. Authors maintained that the extrapolation of the survey density to inshore areas is a reasonable assumption based on reports of high densities observed by commercial harvesters in those areas. Since inshore areas are preferred habitat for sardine, it is likely that the inshore regions have a higher density than the WCVI core survey region.

Acoustic surveys

Some time was spent discussing the potential use of acoustics to help assess the sardine biomass in British Columbia waters. Differences in fish size, vertical distribution and habitat would likely complicate the extension of U.S. results to Canadian waters. It was noted that current Canadian research platforms lack the appropriate equipment for acoustic assessment of sardines. Efforts to coordinate future surveys with the U.S. are underway.

Stock status

Attention was drawn to the fact that recruitment indices observed in recent years are low, but similar to what was observed a decade ago. Given favourable environmental conditions, the sardines may recover from the current decline, just as was observed in 2003. Authors refocused attention to the currently observed declining trend. American colleagues agreed that all independent surveys (Canadian trawl survey, American aerial surveys, Daily Egg Production Model (DEMP), Spawning Stock Biomass (SSB) conducted coastwide in 2010 reported a consistent decline in the sardine population which cannot be dismissed.

International relations

The consideration of fish size and its contribution to recruitment was discussed. Larger, older fish have been found to migrate further north possibly followed by younger, smaller fish. Larger fish are also known to have greater fecundity. Catch of larger fish in Canadian waters may be removing highly reproductive fish from the population. However, it was also noted that the U.S. harvests smaller fish (age 1 and 2) which are pre-recruits, and are equally important to long-term stability of the stock.

The general consensus was that increased cooperation between U.S. and Canadian scientists in research studies as well as policy implementation is encouraged. The U.S will be conducting spring and summer coastwide surveys in 2012 and Canadian involvement is welcomed. In the winter of 2011, the U.S. will undergo a major review of its sardine assessment model. Modifications to the U.S. sardine assessment methodology will impact the Canadian harvest guidelines since the current framework makes use of the U.S. coastwide biomass estimate.

Migration

Concern was expressed regarding the calculation of a migration rate with compounded uncertainties associated with each of the U.S and Canadian biomass estimates. Some committee members cautioned against drawing the conclusions of significant changes to migration rate given the uncertainty of these two independent estimates.

SUBCOMMITTEE CONCLUSIONS

- The subcommittee accepted the paper subject to revisions.
- The subcommittee concluded that at this time, the current Harvest Control Rule is the most appropriate method to calculate harvest options.
- The subcommittee accepted the incorporation of inshore area biomass estimates because the core survey area does not reflect the overall distribution of sardines in Canadian waters and endorses the use of inshore area estimates in the harvest control rule for the provision of management advice for the 2011-12 fishing season.
- Incorporation of the inshore area estimates to the harvest control rule results in a 27.2% migration rate estimate, and a harvest option of 21,917 tonnes.

SUBCOMMITTEE RECOMMENDATIONS

A range of recommendations for future research were suggested to improve the assessment of sardine biomass in B.C waters. The advice put forth by the subcommittee includes:

- Incorporation of environmental indicators and additional survey methodologies (e.g. aerial coverage, satellite imagery) should be explored to complement the trawl survey in future assessments;
- Further exploration of the trawl survey data to evaluate the effect of climate and environmental conditions on sardine migration, and its utility as a predictive tool. Calibrate past surveys if ocean conditions are found to have an effect;
- Comparison of transect and randomized grids using post stratification to assess variability in abundance estimates;
- Validation of the assumptions about sardine distribution and abundance in inshore areas and the core area as well as catchability for trawl surveys;
- Addressing the apparent uncertainty of age determination of older fish (4+) due to the importance of this information in making accurate stock assessments; and,
- Industry, academia, and tri-national government agency collaborations are encouraged for ongoing studies of sardines and their role in the ecosystem.
- The subcommittee recommends that in the event that inshore area volume (103.9 km^3) is used in future assessments, it should remain fixed.

ACKNOWLEDGEMENTS

Thank you to Jackie Detering for rapporteuring the review and to Janeane MacGillivray for coordination of the documents, organization of the meeting and managing the webinar. Thanks to Marilyn Joyce for advice on managing the meeting and contributing to the production of the science advice report.

APPENDIX A: AGENDA

PACIFIC SARDINE

Regional Advisory Process
Centre for Science Advice Pacific
January 18, 2011
Nanaimo, British Columbia
Chairperson: Sean MacConnachie

Tuesday, January 18, 2011

Working Paper to be reviewed: Assessment of Pacific sardine in British Columbia waters, with an emphasis on seasonal abundance and migration estimates *by Flostrand et al*

9:00	Introductions	Sean MacConnachie
9:10	Review Agenda & Housekeeping	Sean MacConnachie
9:20	CSAS Overview & Procedures	Sean MacConnachie
9:40	Review of Terms of Reference as pertains to assessment of Pacific sardine biomass, migration and harvest advice	Sean MacConnachie & RAP Participants
9: 45	Presentation of Working Paper	Jake Schweigert
10:00	***Break***	
10:20	Questions of Clarification	RAP Participants
10:45	Presentation of Reviews & Authors' Responses	Reviewers & Author(s)
12:00	***Lunch Break***	
1:00	Discussion	RAP Participants
2:30	*Break*	
2:50	Review Science Advisory report: Building Agreement on Conclusions, Recommendations, Advice and Future Work	RAP Participants
4:30	***Adjournment***	

APPENDIX B: ATTENDEES

First Name	Last Name	Affiliation
Sandra	Bassett	DFO
Jennifer	Boldt	DFO
Jackie	Detering	DFO
Marilyn	Joyce	DFO
Sean	MacConnachie	DFO
Lisa	Mijacika	DFO
Brenda	Spence	DFO
Ron	Tanasichuck	DFO
Marc	Trudel	DFO
Randy	Webb	DFO
Sandy	McFarlane	DFO Scientist Emeritus
Cynthia	Johnston	DFO
Jake	Schweigert	DFO
Mary	Theiss	DFO
Sarah	Busch	DFO
Peter	Midgley	DFO
Ken	Cooke	DFO
Matt	Thompson	DFO
Dennis	Chalmers	Province of BC
William	Gladstone	Heiltsuk First Nation
Lorena	Hamer	HCRS
Bill	Wilson	SIAB & Aboriginal Fishing Vessel Owners
John	Lenic	SIAB/CPSA
Mitch	Ponak	SIAB/CPSA
Dave	Schmidt	Quatsino First Nation/ SIAB

Kevin	Hill	NOAA
Nancy	Lo	NOAA
Earl	Newman	Heiltsuk First Nation

APPENDIX C: TERMS OF REFERENCE

Terms of Reference

Assessment of Pacific Sardine, biological sampling of Pacific Herring, and factors influencing the variability in Pacific Herring egg layers and considerations to stock assessment

Pacific Regional Advisory Process

January 18-20, 2011
Nanaimo, British Columbia

Chairperson: Sean MacConnachie

Background

The *Centre for Science Advice Pacific (CSAP) Pelagics Standing Committee*, along with additional invited participants as required, meet to review information related to assessing pelagic fish stocks. These reviews are based on specific questions outlined in formal *Requests for Science Information and Advice*. A Regional Advisory Process (RAP) is being planned to review three Research Documents and one Science Advisory Report pertaining to Pacific sardine or Pacific herring in British Columbia waters.

Working Paper 1: Assessment of Pacific sardine in British Columbia waters, with an emphasis on seasonal abundance and migration estimates

Context

Following a RAP conducted in April of 2009, harvest advice in British Columbia (BC) has been based on a 3 year running average of the most recent BC migration rate estimates, a current estimate of the coastwide adult stock biomass (from the US assessment) and applying the US harvest rate (15% in recent years). Sardine seasonal migration into BC has been estimated from west coast Vancouver Island (WCVI) midsummer surface trawl surveys. Seasonal abundance and migration estimates based on WCVI trawl survey data have been considered to be minimum estimates because they don't include other regions of the province where sardines also occur midsummer. Following a meeting with industry in June of 2010, an agreement was made to investigate the feasibility of developing a harvest strategy based entirely on the results of the annual west coast of Vancouver Island trawl survey. A need to investigate the possibility of assessing sardine abundance in other unsurveyed areas of the coast was also identified.

Objectives

1.1 To review the feasibility of developing a seasonal estimate of sardine biomass in the Canadian zone from the summer research trawl survey data, independent of the US stock assessment.

1.2 To identify issues (e.g. biological and technical, including information gaps) associated with changing from the methodology adopted in April 2009.

1.3 To provide advice on seasonal abundance and/or migration to apply to harvest control rules and setting quotas for the 2011/2012 fishing season

Working Paper 2: Biological sampling of BC herring: Analysis of sampling requirements for characterizing age structure and other biological characteristics of fisheries and spawning populations

Context

Given reductions in resources for data collection following the Larocque court decision, concern has been expressed about the adequacy of ongoing data collection programs. Consequently, there is ongoing interest in exploring the cost-benefits and tradeoffs of varying spatial and temporal sampling coverage versus the precision of parameter estimates. Conclusions and recommendations from several past RAPs have identified this need. Furthermore, these types of evaluations are required in order recognize whether datasets in the time series can be used to distinguish different biological characteristics between regional stock groupings. Despite area closures in 3 of the 5 major regional assessment areas, the biological sampling and spawn survey programs operate annually. However, there is some concern about the adequacy of the biological sampling program in providing information on fish size and age composition of major herring stocks for stock assessment analysis and modelling.

Objectives

2.1 To review an investigation which explores effects of varying spatial and temporal sampling coverage to adequately characterize fish size and age structure of Pacific Herring stocks in the major assessment areas.

2.2 To determine if existing data can be used to evaluate whether the accuracy and precision of estimates of biological characteristics has changed over time.

2.3 To determine if data trends of biological characteristics are indicative of similarities or differences between stocks in some areas (e.g., Central Coast (CC) subareas 6, 7, and 8).

Working Paper 3: Factors influencing the variability in Pacific herring egg layers and considerations to stock assessment

Context

Although herring spawn data have been collected for over 50 years, a detailed study of factors that influence the number of egg layers deposited has not been conducted. A better understanding of factors governing the density of spawn deposition will provide valuable information on herring reproduction. The assumption that low numbers of egg layers in a specific spawning site is symptomatic of a low spawning biomass should be investigated since this view may be implied by stock assessment sampling and modelling.

Mortality of eggs during spawning has been examined and documented at most major spawning cites, both in the Atlantic and Pacific Ocean. The loss of eggs during spawning has special relevance to Pacific herring stock assessments that rely on a quantitative index of herring spawn as a key component for annual assessments. A particular concern is that as the financial and logistical support for spawn surveys has diminished the timing of the surveys may be relatively later than during earlier surveys. Relatively later assessments of spawning by SCUBA surveys could result in an under-estimate of spawn, hence an underestimate of the spawning biomass. The potential scale of such possible under-estimates is uncertain, but even a relatively small daily loss (~2%) would result in a total loss of over 25% during a 14-day incubation period. A daily loss of 5% would result in total reduction of more than 50% during the same period. Also, there are other uncertainties that affect the estimates of spawn survival, including density dependent survival of eggs, with survival to hatching being lower in very high densities, etc. It is

plausible that this is a concern for areas of the BC coast where spawn has tended to concentrate in fewer areas in recent years.

Objectives

3.1 To review information related to physiological, ecological and behavioural controls that affect Pacific herring spawning behaviour and factors associated with the estimation of the number of egg layers.

3.2 To review information related to factors that affect the estimation of variability in egg layers.

Expected Publications

CSAS Proceedings

CSAS Science Advisory Report (1), based on Pacific sardine assessment

CSAS Research Documents (3)

Participation

DFO Science Branch
DFO Fisheries and Aquatic Management Branch
Commercial and recreational fishing Interests
First Nations organizations
Non-government organizations
Academia

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Cleary, J.S., Schweigert, J.F., Haist, V. 2010. Stock assessment and management advice for the British Columbia herring fishery: 2009 assessment and 2010 forecasts. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/079. vii + 81 p.

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Schweigert, J., McFarlane, G., Hodes, V. 2010. Pacific sardine (*Sardinops sagax*) biomass and migration rates in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/088.

APPENDIX D: DETAILED REVIEWS

Comments on Flostrand et al. 2010. Evaluation of Pacific sardine (Sardinops sagax) stock assessment and harvest guidelines in British Columbia.
By Marc Trudel

p. 2, first paragraph: The following sentence can be interpreted in different ways: "Recent trawl surveys, however, have indicated a larger biomass of sardine in Canadian waters during the summer suggesting that the northward migration rate is greater than 10%. " Does that mean that there is overall more sardines on the west coast of North America (including in Canada), or that the proportion of sardines in Canadian waters has truly increased? Is this also because of changes in methodologies?

p. 2, second paragraph: Was there a nighttime survey conducted in 2007?

p. 3, second paragraph: How did you estimate the weight of the catch.

p. 3, Trawl densities: why just 2000 bootstrap estimates of the mean? You might need a justification for this (see figure 3). Basically, the data are not normally distributed, with a large number of zero catches.

p. 3-4. The inshore biomass was estimated by inflating the west coast of Vancouver Island biomass by about 1.207, or in other words assuming that the biomass off the west coast of Vancouver Island per unit volume was the same for the inshore areas. Is this a reasonable assumption?
1.207 = (inshore volume + WCVI volume)/WCVI volume

p. 4. Migration rates: The approach used to estimate migration rates appear to differ from what Ware derived (daytime sampling, nighttime sampling, harvest rates). Is there any way to reconcile the two methods?

p. 4. Realized harvest rates: Does the Canadian biomass include your extrapolation to the inshore areas? (this is answered on p. 6 in the Realized harvest rates section)

p. 5. US harvest control rule: Is it reasonable to assume that 87% of the coast wide sardines reside in US waters, when possibly 22% of the US-Canada biomass is in Canada? Is it reasonable to assume that this value has no effect n the Canadian and US fishing dynamics?

p. 5. Transboundary harvest control rules: Does that mean that you are not including any estimates of the proportion of sardines in US waters in your calculations, or that you set it as a constant 87%?

p. 5. Length and age: What is the purpose of this section.

p. 6. Biomass and migration rate: The annual decrease for the biomass of sardines off WCVI is roughly 71,000 tonnes per year compared to 188,000 tonnes per year coastwide. As it is, the 2010 biomass of sardines off WCVI is approximately one fifth of the 2006 biomass, and about half of the 2006 biomass for the 2010 biomass on a coastwide basis. Is this because of over harvesting?

p. 7. Canadian harvest rule: The use of the WCVI migration rate is conservative relative to the inshore. Given the high uncertainty associated with the extrapolation of the WCVI biomass to the inshore area, wouldn't it be more prudent (or precautionary) to only consider the migration to WCVI rather than to the whole coast?

p. 7. Alternative harvest control rule: Wouldn't be prudent to allow fishing only when the biomass exceeds a certain threshold as is currently done with the US model or for herring in BC?

p. 7. Transboundary harvest control rule scenarios: "can result in a collective transboundary harvest rate that exceeds the target rate of 15% applied in each country." I'm not sure what this sentence mean. Does that mean that the overall harvest rate exceed15% of the coastwide biomass, or that it exceeds 15% of the biomass in each country? This is obviously not the case for Canada, as the harvest rate is set at 15% of the biomass in Canadian waters (irrespective of the migration rate).
"The effect of the first scenario is based on the fact that neither the US nor the Canadian management of sardine fisheries is factoring the seasonal change in fish distribution and both countries apply a 15% harvest rate to a population that spends only a portion of the year in their jurisdiction."
Does that really matter? The issue is primarily because you assume that either there is no fish outside US waters, since you did not even adjust the coast wide estimate for the proportion in US vs Mexico waters. Then as the proportion of sardine in Canadian waters increases, the proportion in US waters should decrease further. This is why the total harvest exceeds 15%.

p. 7. Length and age: These results are interesting. Notably, it looks like there is a gradient in size from south to north (small to large). However, I don't see the link (yet) with the rest of the paper.

p. 8. Trawl densities: Can't you use hydroaccoustics to determine the vertical distribution of sardines in your surveys? Have you considered using hydroaccoustics to estimate the overal biomass of sardines? Results from surveys conducted in US waters might differ as they appear to be catching smaller sardines which may occupy a different depth strata.

p. 9, first paragraph. 2006 was actually the highest migration rate off WCVI and 2008 was the third highest of the time series. So there doesn't seem to be an association between cold water and migration to BC waters, at least within that time series. The extent of their northern extension is likely linked to temperature (1998 and 2005 come in mind). Figure 12 does not show the migration rate into BC waters.

p. 9, second paragraph. So the assumption that the timing of the DFO survey correspond to the peak biomass appears, for the most part, reasonable (albeit not perfect).

p. 9. Inshore areas: Does that mean that DFO's survey should be modified to include these inshore areas, since they contain an unknown, but potentially large, proportion of sardine biomass in BC waters.

p. 10. Realized harvest rates and transboundary effects: The recalibration of TACs seems to be a reasonable interpretation of the higher proportion of the biomass being caught in 2010 relative to previous years. This interpretation could be verified directly by comparing the realized catches to the previous TACs.

p. 10, second paragraph. A fifth reason could be simply due to increased effort and markets.

p. 10, third paragraph. The simulations also do not account for the distribution of the stocks in both countries. For instance, if 60% of the fish migrate to Canadian waters, than obviously you can't have 87% of the fish residing in US waters (though they may be transiting there). And obviously, uncertainties in biomass estimates will affect our perception of the catch that occurs in each region. As the authors argue, the effect of decreasing biomass on realized catch may also affect the proportion of the stock being actually captured. Should Canada also adopt a minimum threshold like the US has for sardines or Canada has for herring? Especially given that biomass appears to have been decreasing since 2006 on a coastwide basis and in the DFO surveys? The last line of that paragraph is especially of concern.

p. 11, first paragraph. Given the issue associated with increasing and decreasing trends in abundance in terms of undercatching and overcatching sardines (respectively), is there a way to adjust the pre-season estimate for these trends using biomass data on earlier age-classes?

p. 12. Harvest advice: given the observed declining trend in sardine biomass of about 71,000 tonnes per year, it might be worth to take this value into consideration before adopting a harvest rate in 2011. The parallel declining trend observed in BC and coastwide should be of concern and may indicate poor recruitment and high harvest rate (on poorly recruiting fish). The low temperatures associated with the 2010 La Nina may further decrease the recruitment of these warm water fish.

p.12. Acknowledgements: It is nice that you acknowledge Rowan Haigh for providing the R code for the Binomial-Gamma distribution, but you actually did not use this in your analysis. So there is no point in mentioning it here.
p. 20. Table 9. The US harvest rate need to be corrected for the proportion of fish in the US (currently set at 87%).

Editorial comments
p. 2, first paragraph: Add "was" in this sentence: "migration mirrors that was observed"
p. 2, second paragraph: Change "had" to "has" in this sentence: "As the Canadian fishery has expanded"
p. 3: Trawl densities: put a reference for bootstrapping (for instance, Efron. 1981. Biometrika)
p. 13-14. References. Scientific names need to be italicized.
p. 16, Table 2. Quartiles are not very informative when many 0s are observed. The bootstrap mean is probably your best metric along with the bootstrap confidence limits.
p. 18, Table 6. Reduce the precision of the WA+OR Coastwide harvest rate to only one digit like the other columns. What is the point of having the PNW column? This is redundant, as it is the sum of BC + (WA+OR), both of which are readily available in the table.
p. 25-26: The precision of the R2 and regression models can be decreased to only 2 digits. Otherwise, it gives the false impression of high levels of precision. Also, where are the confidence limits for the migration rates on Figure 7 and Table 3. Surely, this is an estimate that has uncertainties.
p. 27. Figure 8. What is on the y-axis? Proportion?
p. 28. Figure 9A, 9B: What does N represent?
p. 32. Figure 13. This figure is not referred to in the text and should be deleted.

Review by Robert Emmett of
'Evaluation of Pacific sardine (*Sardinops sagax*) stock assessment
and harvest guidelines in British Columbia.'

Overall I found the report: 'Evaluation of Pacific sardine (*Sardinops sagax*) stock assessment and harvest guidelines in British Columbia', to be very well written. I believe the data presented in Figures and Tables were very clear.

I found the Harvest Advice to be well documented and presented in a very clear manner. Trawl densities methodology and confidence intervals construction using bootstrapping is a very standard procedure. It would have been appropriate for the authors to provide a reference on bootstrapping.

Methodology for biomass estimates calculations were also clearly defined and easy to follow. As was realized harvest rates, and Canadian harvest control rule.

I would highlight that in the US we do not have a TAC but it is called a Harvest Guideline (HG) in Hill et al. (2010) but it is equivalent to what the authors are calling a TAC in Canada. Some things that should be addressed: The authors highlight that in the size and age of California commercial landings are much smaller and younger than BC sardines. There is a reason this is true. When the large fish are off CA in spring they are in spawning condition/areas and they appear to be offshore and away from the nearshore oriented commercial fleet. Spring size/age structure off California is clearly shown in the following papers and should be referenced. Data from these surveys may be more appropriate.

Lo, N. C. H., B. J. Macewicz, and D. A. Griffith. 2009. Spawning biomass of Pacific sardine (*Sardinops sagax*) off California in 2009. U.S. Dep. Commer., NOAA Tech. Memo., NOAATM-NMFS-SWFSC-449. 31 pp.
http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-449.pdf

Lo, N. C. H., B. J. Macewicz, and D. A. Griffith 2009. Biomass and reproduction of Pacific sardine (*Sardinops sagax*) off the Pacific northwestern United States, 2003–2005. Fish. Bull. 108:174–192.

My copy did not have page numbers – these would be helpful when editing or discussing the report.

The largest error I found in the paper was in Table 9. The authors did not account for the US distribution (0.87) in their calculations of US TAC – as stated under US harvest control rule formula, the TAC (or HG) is = (Biomass – Cutoff) * Fraction * Distribution
Cutoff = 150000 (minimum biomass to preserve)
Fraction = 0.15 (proportion to be harvested)
Distribution = 0.87 (proportion in US waters)

In Table 9 the authors did not include US Distribution (0.87) in their calculations. This inflated the US TAC values. For example for 2010 and a biomass of 537,173 Coast wide Biomass, US TAC would actually be 50,526 tonnes, not 58,076. This then would reduced the realized HR in the US coast wide and the US+BC coast wide. So in 2011 recent US Pacific Fisheries Management Council ruled that 2011 US TAC (Harvest Guideline) was set to 50,526 tonnes.

See attached PDF of the Nov 2010 Decisions by the US Pacific Fisheries Management Council.

Using the new calculations in Table 9 still indicates that overall US BC harvest can be over 20% harvest rate, especially when stock abundance is high and BC migration rate is high.
The authors note that realized harvest rates over 15% can occur – especially if stocks are declining from high values. I believe they should add to this discussion and address the issue, can sardine handle 20% harvest rate? I believe from what we know about this stock and other pelagic fish stocks are that they can handle a high (20% realized harvest rate) under some conditions. For example, if the ocean is warmer than normal and successful recruitment events – especially off the Northwest US occur over a number of years. An excellent example of a growing stock would be in the 1990s or 2004-2005 (Figure 12). However, when spawning success is poor – such as has been observed since 2006, a more conservative approach would be warranted.

It is also clear that % migration rate into Canadian waters is controlled by oceanography. Perhaps a discussion regarding this would be appropriate. It may be appropriate to tie actual harvest to an "expected" % migration rate given the oceanographic conditions. The US uses oceanographic conditions (temperature) to set it's Harvest Guideline, I see no reason that with a little analysis an expected % migration into Canada waters could be identified from winter/spring temperatures – before the Canadian sardine fishery really gets started.

A little house keeping:
Biomass section – when inshore areas is use please put (IA) next to it. IA is used in the figures but not clearly identified in the text what it means.

In the **References** – Emmett et al. 2005 – Italicize *Sardinops sagax*
Same thing for Lo et al. 2010, and Schweigert et al. 2009.

McFarlane et al is now published – i.e. 2010 – CalCOFI Rep. 51:162-168.
Schnute and Haigh 2003 – groudgish – should be groundfish

The authors did an outstanding job making a relatively complex issue very understandable. I hope my review was helpful. I'm sorry that I will be unable to call into the discussion on this matter on 18 January, but I will be engaged elsewhere.
Sincerely,
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